

REMARKS

The Applicant has personally met with Examiner (Dr. Palabrica) and engaged in a detailed one-on-one discussion in good faith to strive to ameliorate questions cited by Examiner in previous Office Actions. Applicant explained concepts of acoustic thermonuclear fusion, demonstrated operability of invention apparatus in specification, discussed differences with prior art, discussed the aspect of removal of non-condensable gases from nucleated bubbles (to obtain substantially vapor-filled bubbles), discussed the various independent confirmation studies conducted and reported in the literature since 2003 and discussed the theoretical foundations associated with the claim of thermonuclear fusion induction during implosion of substantially deuterated vapor filled bubbles following the methods outlined in this application.

Evidence and demonstration for thermonuclear (fusion) nature of the present application

In addition, the applicant discussed with Examiner Dr. Palabrica the published findings (Fig. 7c) in the premier journal *Physical Review E*, Vol. 69, 036109-1 to 11, by Taleyarkhan et al., 2004 which demonstrates experimentally that D-D fusion neutrons of 2.45 MeV in energy as required for thermonuclear fusion are emitted in a time –correlated manner with the emission of sonoluminescence (SL) light flashes clarifying and demonstrating that the fusion reactions are occurring under hot, compressed conditions for the method and apparatus of this present invention application. This *Physical Review E* (2004) by Taleyarkhan et al. article has been previously transmitted under separate cover to USPTO as part of an IDS package dated June 1, 2007.

The first page and Fig. 7 from the 2004 *Phys.Rev.E* article by Taleyarkhan et al. are excerpted and shown below for the direct viewing by the examiner.

PHYSICAL REVIEW E 69, 036109 (2004)

Additional evidence of nuclear emissions during acoustic cavitation

R. P. Taleyarkhan,^{1,*} J. S. Cho,² C. D. West, R. T. Labey, Jr.,³ R. I. Nigmatulin,⁴ and R. C. Block²

¹Purdue University, West Lafayette, Indiana 47907, USA

²Oak Ridge Associated Universities, Oak Ridge, Tennessee 37830, USA

³Rensselaer Polytechnic Institute, Troy, New York 12180, USA

⁴Russian Academy of Sciences, 6 Karl Marx Street, Ufa 450000, Russia

(Received 13 May 2003; published 22 March 2004)

Time spectra of neutron and sonoluminescence emissions were measured in cavitation experiments with chilled deuterated acetone. Statistically significant neutron and gamma ray emissions were measured with a calibrated liquid-scintillation detector, and sonoluminescence emissions were measured with a photomultiplier tube. The neutron and sonoluminescence emissions were found to be time correlated over the time of significant bubble cluster dynamics. The neutron emission energy was less than 2.5 MeV and the neutron emission rate was up to $\sim 4 \times 10^5$ n/s. Measurements of tritium production were also performed and these data implied a neutron emission rate due to D-D fusion which agreed with what was measured. In contrast, control experiments using normal acetone did not result in statistically significant tritium activity, or neutron or gamma ray emissions.

DOI: 10.1103/PhysRevE.69.036109

PACS number(s): 89.90.+n

ADDITIONAL EVIDENCE OF NUCLEAR EMISSIONS . . .

PHYSICAL REVIEW E 69, 036109 (2004)

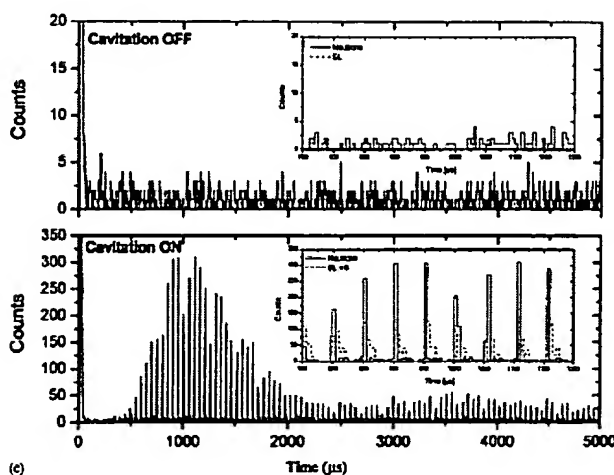
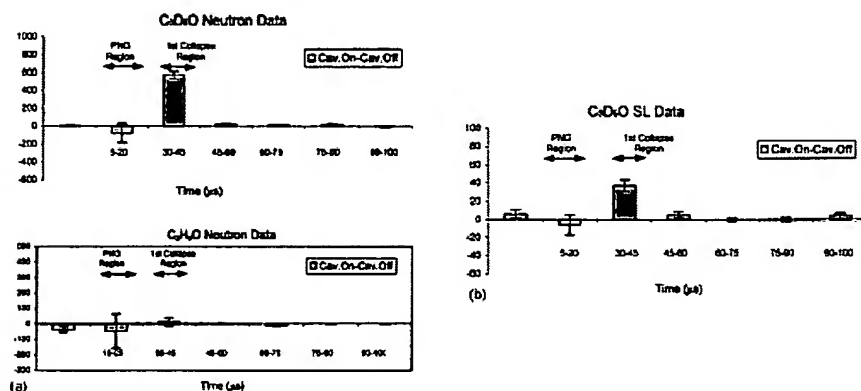


FIG. 7. (a) Change in neutron counts for chilled acetone with cavitation for the first 100 μs (acetone at 0 °C; PNG drive frequency ~ 200 Hz; acoustic forcing frequency ~ 19.3 kHz; error bars are 1 SD). (b) Corresponding change in SL counts for acetone for first 100 μs. (c) Composite plots showing time correlation between neutron and SL counts over 5000 μs for cases of cavitation off and cavitation on (C_2D_6O at ~ 0 °C; PNG operation at 200 Hz). (d) Time correlation between neutron and SL counts between 0.5 and 2.0 msec. (Cavitation on-cavitation off; C_2D_6O at ~ 0 °C; PNG operation at ~ 200 Hz.) (e) Variation of aggregate neutron and SL counts in peak and in-between peak regions between 0.5 and 2.0 msec. (Cavitation on-cavitation off; C_2D_6O at ~ 0 °C; PNG operation at ~ 200 Hz. Neutron counts per channel in peak channels are about 50 times larger than for remaining channels; the corresponding SL counts per channel in peak channels are about 5 times larger.)

Also discussed with the examiner on May 24, 2007 was the theoretical foundation that affirmed the claim of supercompression-induced thermonuclear fusion for the experimental conditions of the method used for the current application. This theoretical foundation takes into account all relevant physics and chemistry of the condition. It has passed stringent worldwide technical peer reviews and validated by experts as being on sound theoretical foundations and published in the prestigious journal *Physics of Fluids* (Nigmatulin et al., 2005). This theoretical foundation when applied specifically to the method of the present invention confirms thermonuclear conditions (see Fig. 13 of the paper by Nigmatulin et al., 2005 – *Physics of Fluids*, Vol.17, 107106, 2005) with temperatures and pressures reaching in the range of 10^8 K, and 1000+ Mbar, respectively – convincingly thermonuclear fusion conditions. This *Physics of Fluids* journal paper has been transmitted to USPTO under separate cover as part of the IDS package.

The front page and Fig. 13 of the *Physics of Fluids*, 2005 journal paper by Nigmatulin et al. are excerpted below for convenience of the Examiner.

Theory of supercompression of vapor bubbles and nanoscale thermonuclear fusion

Robert I. Nigmatulin,^{a)} Iskander Sh. Akhatov,^{b)} Andrey S. Topolnikov,
Raissa Kh. Bolotnova, and Nailya K. Vakhitova
*Institute of Mechanics, Ufa Branch of the Russian Academy of Sciences, 6 Karl Marx Street,
Ufa 450000, Russia*

Richard T. Lahey, Jr.
*Department of Mechanical, Aerospace, and Nuclear Engineering, Rensselaer Polytechnic Institute,
110 8th Street, Troy, New York 12180-3590*

Rusi P. Taleyarkhan
School of Nuclear Engineering, Purdue University, West Lafayette, Indiana 47907-1290

(Received 10 November 2004; accepted 12 September 2005; published online 25 October 2005)

This paper provides the theoretical basis for energetic vapor bubble implosions induced by a standing acoustic wave. Its primary goal is to describe, explain, and demonstrate the plausibility of the experimental observations by Taleyarkhan *et al.* [Science **295**, 1868 (2002); Phys. Rev. E **69**, 036109 (2004)] of thermonuclear fusion for imploding cavitation bubbles in chilled deuterated acetone. A detailed description and analysis of these data, including a resolution of the criticisms that have been raised, together with some preliminary HYDRO code simulations, has been given by Nigmatulin *et al.* [Vestnik ANRB (Ufa, Russia) **4**, 3 (2002); J. Power Energy **218-A**, 345 (2004)] and Lahey *et al.* [Adv. Heat Transfer (to be published)]. In this paper a hydrodynamic shock (i.e., HYDRO) code model of the spherically symmetric motion for a vapor bubble in an acoustically forced liquid is presented. This model describes cavitation bubble cluster growth during the expansion period, followed by a violent implosion during the compression period of the acoustic cycle. There are two stages of the bubble dynamics process. The first, low Mach number stage, comprises almost all the time of the acoustic cycle. During this stage, the radial velocities are much less than the sound speeds in the vapor and liquid, the vapor pressure is very close to uniform, and the liquid is practically incompressible. This process is characterized by the inertia of the liquid, heat conduction, and the evaporation or condensation of the vapor. The second, very short, high Mach number stage is when the radial velocities are the same order, or higher, than the sound speeds in the vapor and liquid. In this stage high temperatures, pressures, and densities of the vapor and liquid take place. The model presented herein has realistic equations of state for the compressible liquid and vapor phases, and accounts for nonequilibrium evaporation/condensation kinetics at the liquid/vapor interface. There are interacting shock waves in both phases, which converge toward and reflect from the center of the bubble, causing dissociation, ionization, and other related plasma physics phenomena during the final stage of bubble collapse. For a vapor bubble in a deuterated organic liquid (e.g., acetone), during the final stage of collapse there is a nanoscale region (diameter ~ 100 nm) near the center of the bubble in which, for a fraction of a picosecond, the temperatures and densities are extremely high ($\sim 10^5$ K and ~ 10 g/cm³, respectively) such that thermonuclear fusion may take place. To quantify this, the kinetics of the local deuterium/deuterium (D/D) nuclear fusion reactions was used in the HYDRO code to determine the intensity of the fusion reactions. Numerical HYDRO code simulations of the bubble implosion process have been carried out for the experimental conditions used by Taleyarkhan *et al.* [Science **295**, 1868 (2002); Phys. Rev. E **69**, 036109 (2004)] at Oak Ridge National Laboratory. The results show good agreement with the experimental data on bubble fusion that was measured in chilled deuterated acetone. © 2005 American Institute of Physics. [DOI: 10.1063/1.2104556]

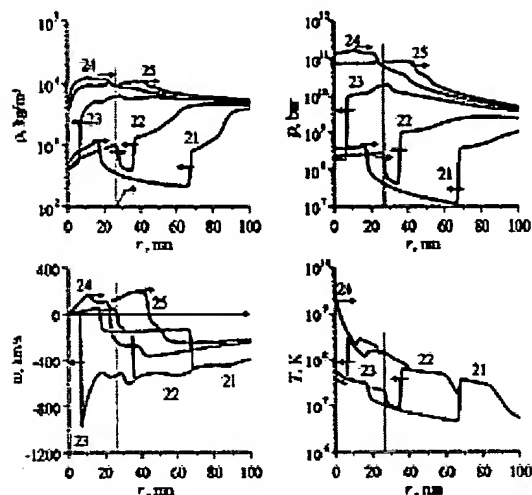


FIG. 13. The final stage of bubble implosion. The vapor parameters distributions near the bubble's center between two interacting shock waves (sub-microsecond, high Mach number, stage). The dashed line indicates the radial position of the maximum neutron production point r^* . The numbers denote times: $t_{21}=t^*-0.11$ ps, $t_{22}=t^*-0.06$ ps, $t_{23}=t^*-0.02$ ps, $t_{24}=t^*-0.01$ ps, where $t_{25}=t^*$.

A critical point at the interface takes place at the moment that is close to t_{12} ($t_{12}=t^*-70$ ns, see Fig. 10), when radius of the bubble $a \approx 110$ μm , velocity of the interface, $w_{La}=w_{Gg} \approx -800$ m/s, and pressure in the bubble is no longer uniform, but there is not yet a shock. At this moment condensation stops because the liquid and vapor on the interface becomes a supercritical fluid ($p \gg p_{cr}=46$ bars, $T \gg T_{cr}=508$ K), and there is no longer any difference between vapor and liquid.

It is interesting that around this moment ($t \approx t_{12}$) the pressure distribution in the liquid is smooth (Fig. 10), but the density distribution looks like a jump near the interface where this density increases three times, however, it is not a jump. The sharp increase of the density follows the sharp drop of the liquid temperature in the thermal boundary layer.

During the subcritical phase of the bubble implosion more than half of the evaporated vapor mass ($m_G \approx 260$ ng) condenses. The final mass of vapor ($m_G \approx 100$ ng) after the transition to a supercritical fluid remains constant and the bubble keeps on contracting from $a \approx 110$ μm to the minimum bubble radius $a_{min} \approx 24$ μm (see Fig. 8), as compared to a minimum radius of $0.3-1$ μm in typical SBSL experiments (Moss *et al.*²¹⁻²³). Significantly, the mass of the highly compressed gas (vapor) in bubble fusion experiments is 10^5-10^6 times larger than in typical SBSL experiments, thus there is more material available to undergo fusion reactions.

Evidence of Operability and Reproducibility

After going with Dr. Palabrica (USPTO examiner) through the video footage of apparatus construction and operation, discussions were on various evidence pieces showing independent validations and replications by other groups with the examiner on May 24, 2007. Following advisement of Examiner, Applicant has respectfully submitted an IDS under separate cover dated June 1, 2007 including three independent replications of published sonofusion results (*Nuclear Engineering and Design* journal paper, Vol. 235, pp.1317-1324 by Xu et al., 2005; Archives of *Trans. American Nuclear Society*, Vol. 95, pp. 736-737, by Forringer et al., 2006; Le Tourneau University, Texas, Press Release, 2006; and the Bugg, W confirmation report dated June 9, 2006 to Purdue University of 2006) of the present invention. Proof of reproducibility and repeatability and confirmation of successful fusion signals attainment following the apparatus and operations of this

Application from published documents are reproduced below for the works of Xu et al. (2005), Forringer et al. (2006); LeTourneau University Press Release (2006).



Available online at www.sciencedirect.com

SCIENCE @ DIRECT®

Nuclear Engineering and Design 235 (2005) 1317–1324

Nuclear
Engineering
and Design

www.elsevier.com/locate/nucengdes

Confirmatory experiments for nuclear emissions during acoustic cavitation

Yiban Xu^{a,*}, Adam Butt^{a,b}

^a School of Nuclear Engineering, Purdue University, West Lafayette, IN 47907 USA

^b School of Aeronautical and Astronautical Engineering, Purdue University, West Lafayette, IN 47907 USA

Received 13 January 2005; received in revised form 14 January 2005; accepted 7 February 2005

Abstract

Confirmatory experiments were conducted to assess the potential for nuclear fusion related emissions of neutrons and tritium during neutron-seeded acoustic cavitation of deuterated acetone. Corresponding control experiments were conducted with normal acetone. Statistically significant (5–11SD increased) emissions of 2.45 MeV neutrons and tritium were measured during cavitation experiments with chilled deuterated acetone. Control experiments with normal acetone and irradiation alone did not result in tritium activity or neutron emissions. Insights from imaging studies of bubble clusters and shock trace signals relating to bubble nuclear fusion are discussed.

Published by Elsevier B.V.

736

Reactor Physics Design, Validation, and Operating Experience

Confirmation of Neutron Production During Self-Nucleated Acoustic Cavitation

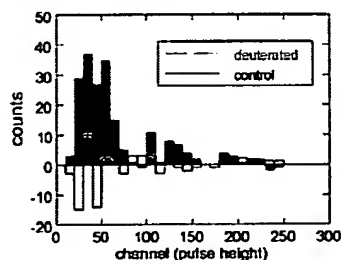
Edward R. Forringer, David Robbins, Jonathan Martin

LeTourneau University, 2100 S. Mobberly Ave., Longview, TX 75602. tedforringer@lenu.edu

Reactor Physics Design, Validation, and Operating Experience

737

present that could compromise our data. While the statistics from the data presented here are not sufficient to distinguish the neutron spectrum from the test apparatus from a Cf-252 spectrum there is an apparent difference. The Cf-252 spectrum is monotonically decreasing from channels 20 through 60 while the spectrum from the test apparatus appears fairly constant in that region. This region of the spectrum is important because it represents the energy range where the bulk of neutrons are expected from deuterium-deuterium fusion.



	Signal	Background	Difference
Deuterated Liquid	81.5	40	41.5±11
Control Liquid	30.5	30	0.5±7.7

SUMMARY

Neutron production during self-nucleated acoustic cavitation of a mixture of deuterated acetone and benzene has been verified with two independent neutron detectors. No neutron production is observed for the deuterated liquid when cavitation is not present, and neutrons are not produced with or without cavitation for the non-deuterated liquid. These observations support previous results indicating deuterium-deuterium fusion during self-nucleated acoustic cavitation of a mixture of deuterated acetone and benzene.

REFERENCES

1. R. P. Taleyarkhan, C. D. West, J. R. T. Lahey, R. I. Nigmatulin, R. C. Block, and Y. Xu, Phys. Rev. Lett. **92**, 015001 (2004).



LeTourneau University News Release

LeTourneau University, P.O. Box 7001, Longview, TX 75607
Fax: (903) 233-3801

Contact: Janet Ragland (903)233-3815
Janet.Ragland@letu.edu

Nov. 17, 2006

BUBBLE FUSION CONFIRMED BY LETOURNEAU UNIVERSITY RESEARCH

(LONGVIEW, Texas)— LeTourneau University physics professor Edward R. "Ted" Forringer, Ph.D., and an undergraduate student have just returned from the American Nuclear Society (ANS) winter conference in Albuquerque, N. M. where they presented two papers confirming the existence of fusion in collapsing bubbles.

It has long been observed by scientists that sound waves in a liquid produce flashes of light when bubbles collapse. This phenomenon is called "sonoluminescence." Professor Rusi Taleyarkhan, Ph.D., from Purdue University was the first to successfully show that these collapsing bubbles can produce fusion of two deuterium nuclei. This process is known as acoustic inertial confinement nuclear fusion, commonly called "bubble fusion." Taleyarkhan's results had been called into question, but now have been substantiated by Forringer and his students.

Claims Amendments

The Applicant thanks the Examiner (Dr. Palabrica) for the interview feedback of the May 24, 2007 interview, where the proposed revised set of Claims were discussed to address the non-compliant amendment dated May 1, 2007 as also the May 1, 2008 non-compliance transmittal which requested amendments to the Claims section.

Accordingly, the Claims section has been revised and amended in accordance with the advisement from the Examiner.